A Linearized Model for Flicker and Contrast Thresholds at Various Retinal Illuminances

Albert Ahumada

al.ahumada@nasa.gov

Andrew Watson

andrew.b.watson@nasa.gov

NASA Ames Research Center

Moffett Field, CA

Temporal Contrast Sensitivity Function (TCSF)

Watson, A. B. (1986). Temporal Sensitivity.

Temporal Impulse Function

$$I(t) = A \, (\Gamma(t, \tau_1, n_1) \quad - a \, \Gamma(t, \tau_2, n_2))$$

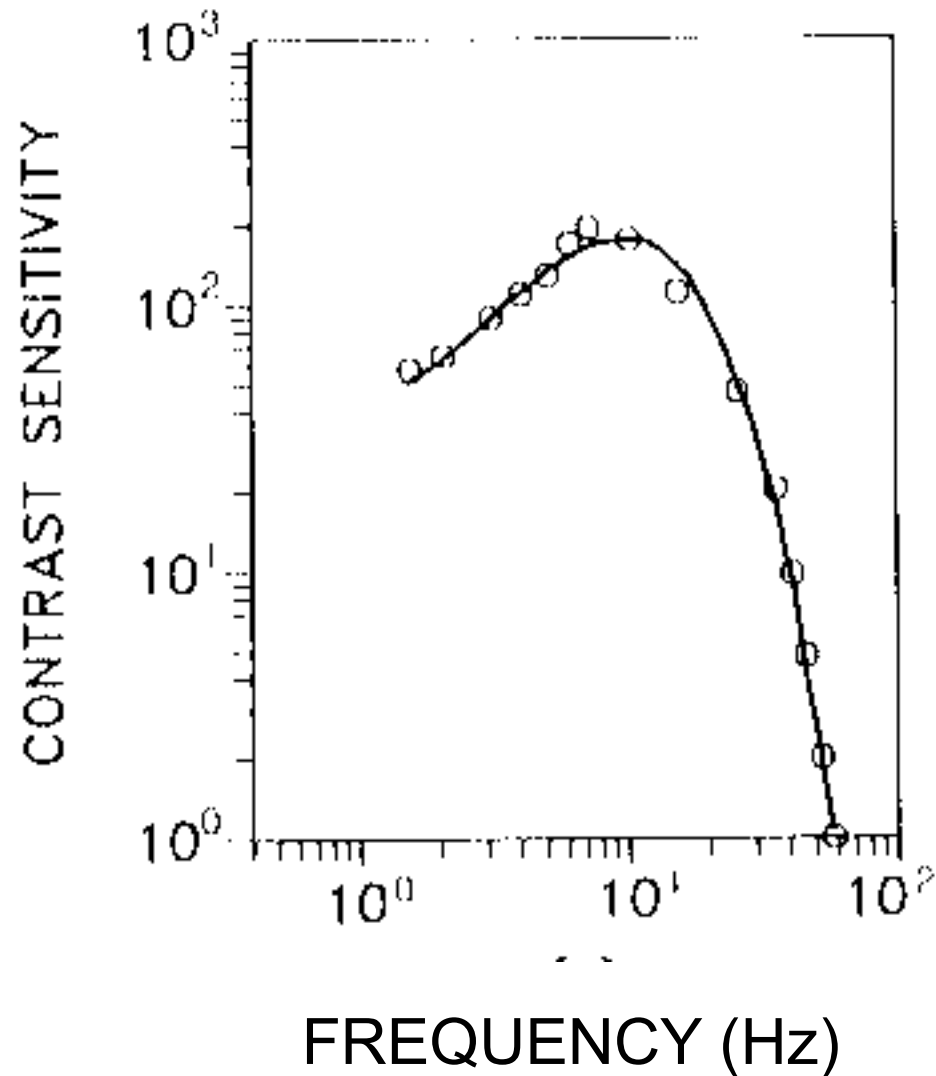$$TCSF(f) = S \, (|(1+i2\pi f\tau_1)^{-n_1} - a \, (1+i2\pi f\tau_2)^{-n_2}|)$$

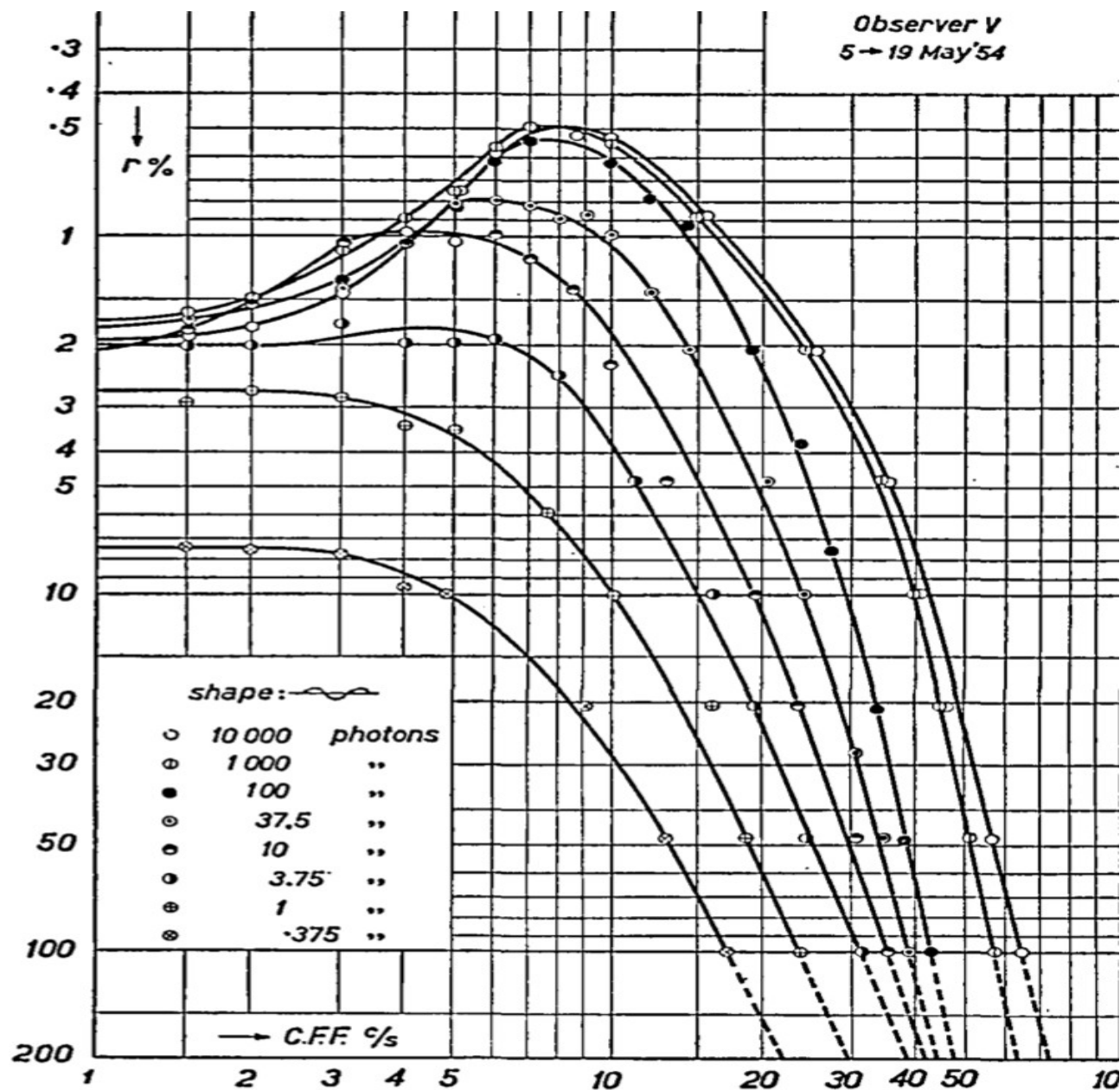Fit to data of deLange (1958 JOSA)

2 deg field, 1000 Td, observer V

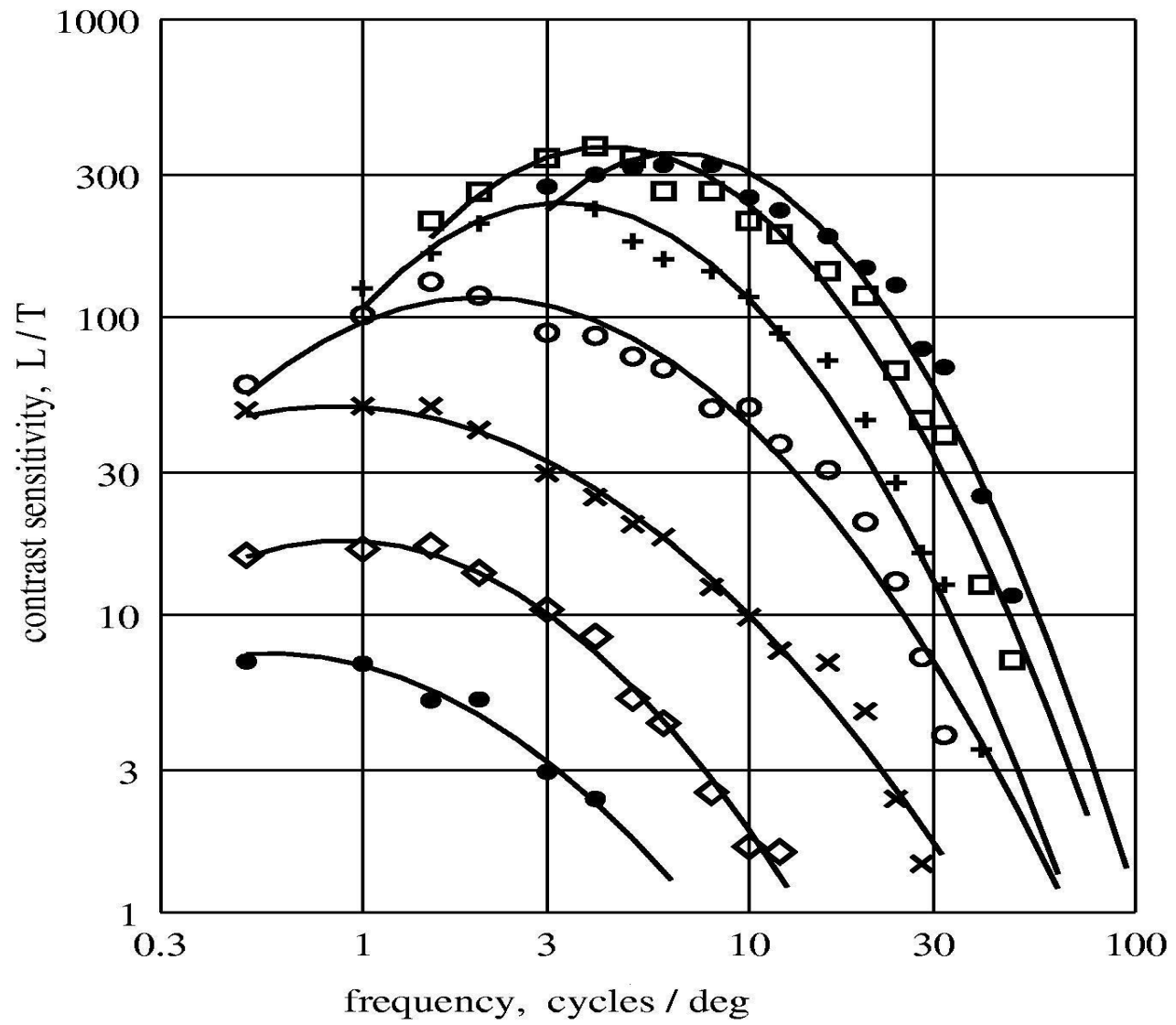$$S = 269; \; a = 0.9; \; \tau_1 = 4.3 \text{ msec}; \; \tau_2 = 1.33 \, \tau_1;$$

$$n_1 = 9; \; n_2 = 10$$
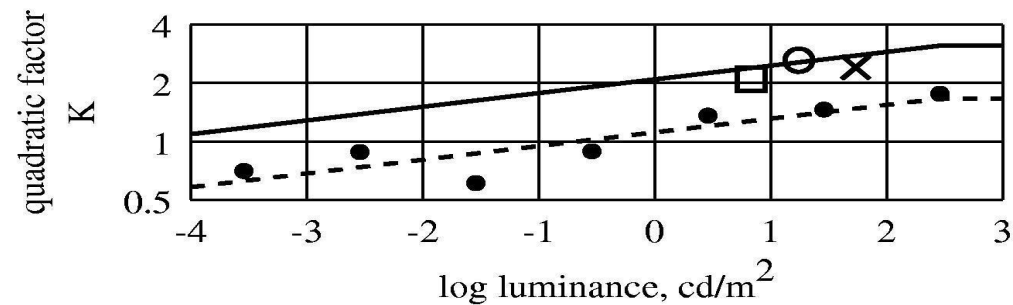
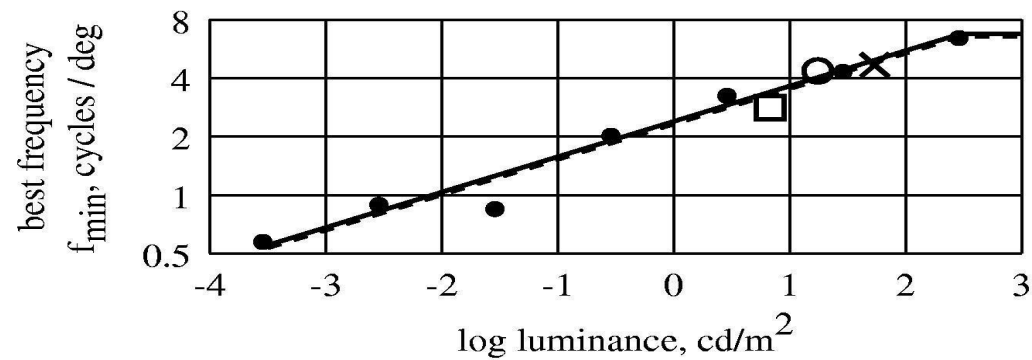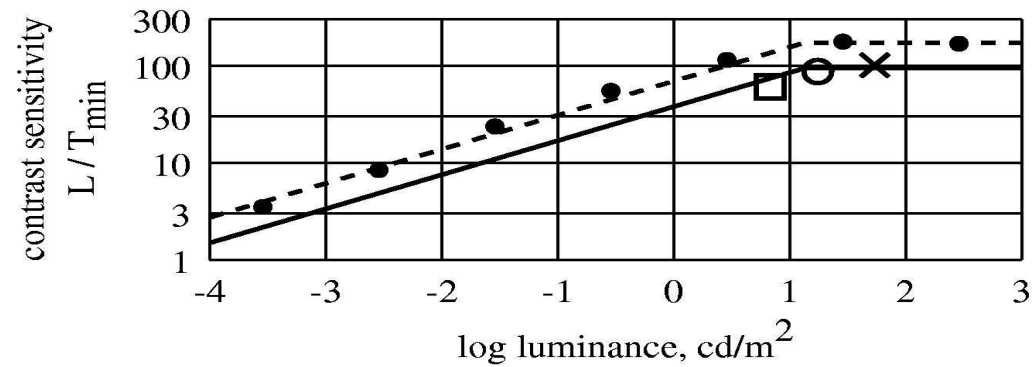# Temporal Contrast Sensitivity Function (TCSF)

FREQUENCY (Hz)

TCSF(illuminance)

CSF(illuminance)

contrast sensitivity, L / T

frequency, cycles / deg
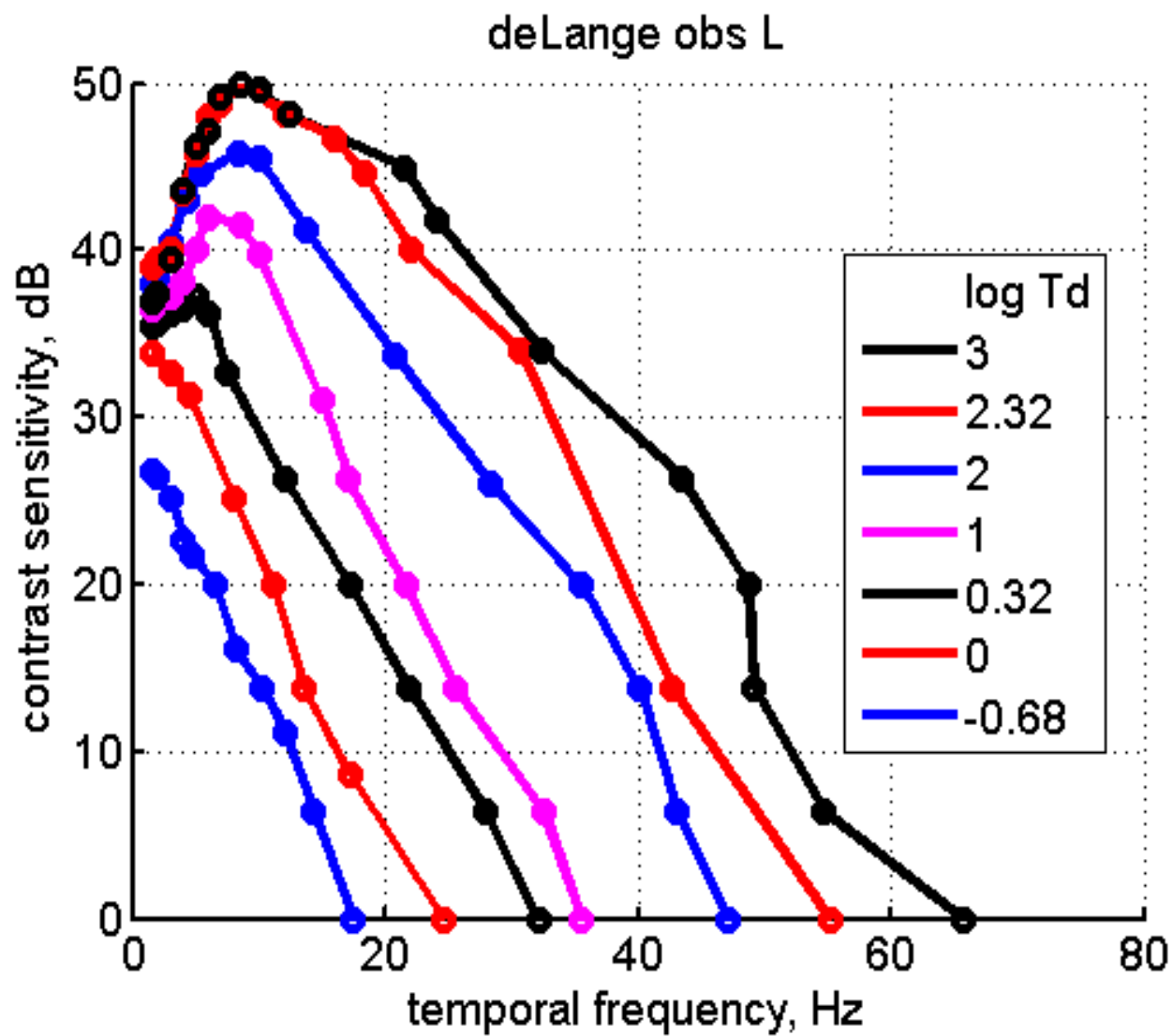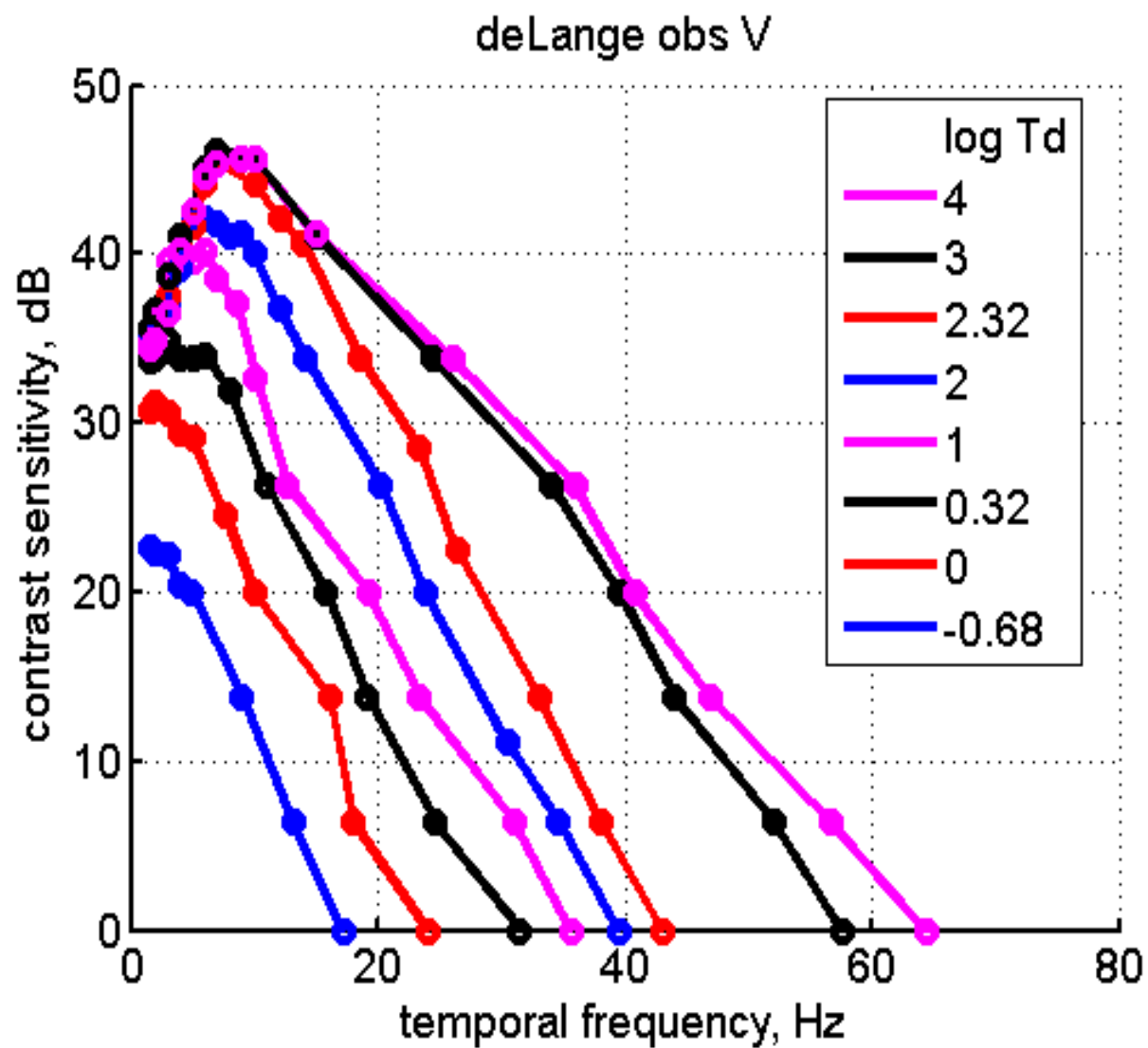
CSF parameters(illuminance)

TCSF(illuminance)

TCSF(illuminance)

Ferry-Porter Law: Linear relation between CFF and log illuminance
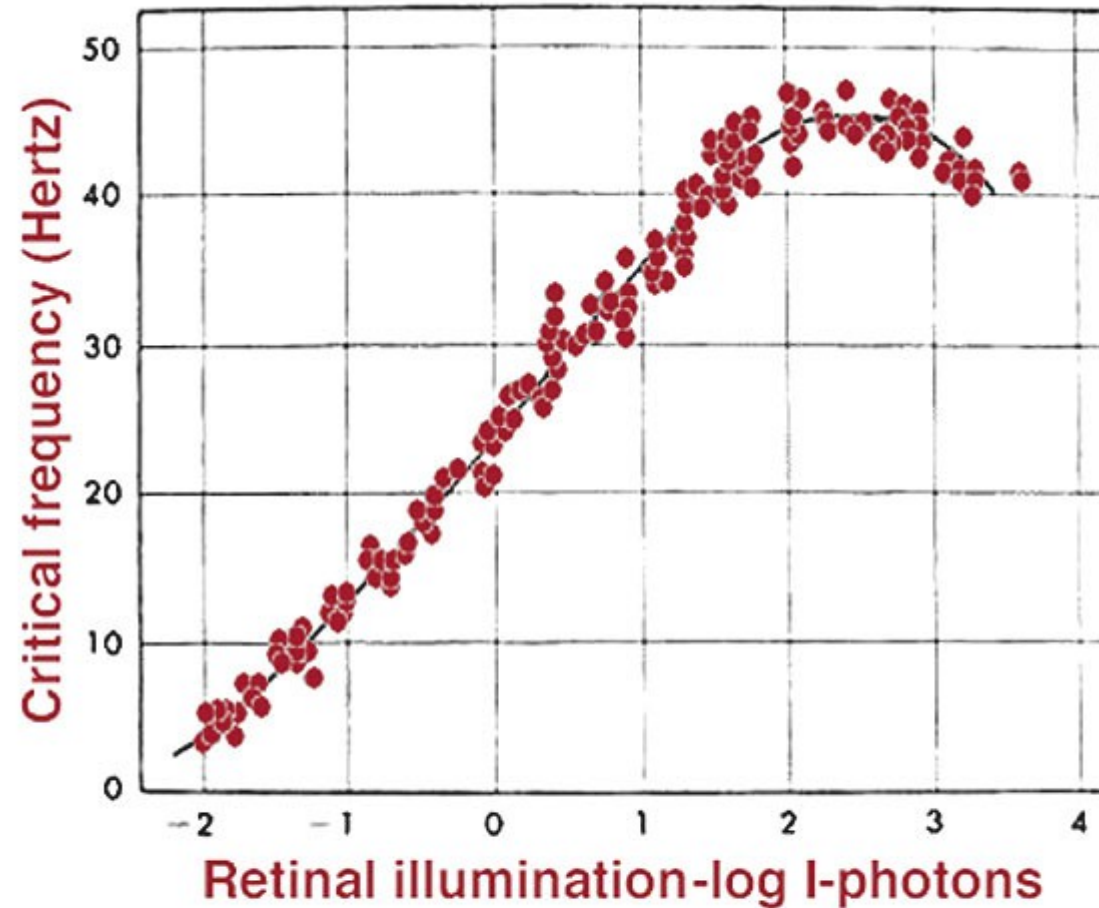

Fig. 7. CFF at the fovea over a range of retinal illuminance (photon = troland) of the test field, showing conformity of the Ferry-Porter Law over four logarithmic units. Hecht and Verrijp's data from Hart Jr, W. M., The temporal responsiveness of vision. In: Moses, R. A. and Hart, W. M. (ed) Adler's Physiology of the eye, Clinical Application. St. Louis: The C. V. Mosby Company, 1987.

Bilinear Model

S = log contrast sensitivity

F = temporal frequency in Hz

I = log retinal illuminance in Trolands

$$S = s_0 + s_F\,F + s_I\,I + s_{FI}\,F\,I$$

or

$$F = f_0 + f_S\,S + f_I\,I + f_{SI}\,S\,I$$

where $f_0 = -s_0 / s_F$; $f_S = 1/ s_F$; $f_I = - s_I / s_F$; and

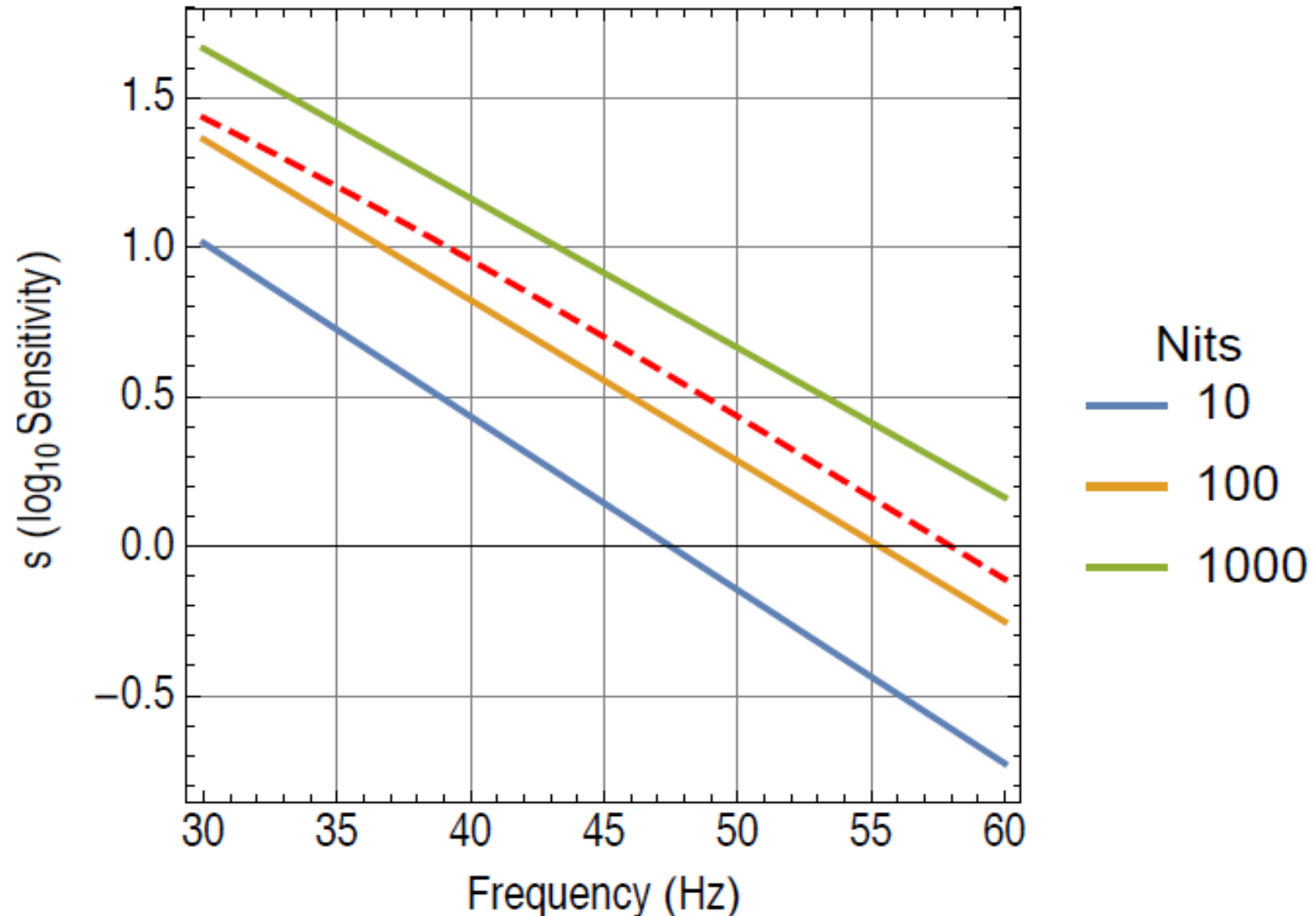$$f_{SI} = 1/(s_F + s_{FI}) - 1/ s_F ;$$

Bilinear Model Fit

de Lange (1958 JOSA)

obs	n	Smax	RMSE	f_0	f_S	f_I	f_{SI}
L	36	1.32	1.5 Hz	23.8	-13.1	12.5	-1.96
V	35	1.46	1.3 Hz	22.9	-13.1	11.1	-4.89

TCSF(F, luminance)
Pupil size from Watson & Yellott (2012 J Vis)

Summary

We have provided a bilinear model for the descending-limb portion of the TCSF, based on the approximate linearity of these limbs in log contrast sensitivity and linear temporal frequency and on the assumption that the Ferry-Porter law remains valid for contrast sensitivity values from 0 to 50 dB.

The model fits the flicker threshold data of de Lange (1958 JOSA) with an RMS error of less than 1.5 Hz.

Acknowledgement